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NONLINEAR OBSERVER FOR ATTITUDE ESTIMATION AND RATE GYRO CALIBRATION

Abstract

The availability of highly accurate attitude information is key for the mission of many spacecraft. It is required to precisely point the payload to the desired observation area, to guide communication antennas, and to maintain the thermal conditions within the designed safety limits. Spacecraft with demanding pointing requirements are often equipped with one or more star-trackers. Star-trackers are equipments composed of an optical system and a light measuring sensor such as a charged coupled device (CCD) imaging sensor. State-of-the-art star-trackers can compute directly its attitude by comparing the measured position of stars with a star catalogue stored in memory. In addition to star-trackers, to achieve high accuracy attitude knowledge, it is necessary to have precise angular rate information. The spacecraft angular rate is typically measured by rate gyros. However, these measurements can be affected by non-idealities such as misalignments, measurement bias, and scale factors. These effects are even more critical because they are often dependent on environmental conditions, such as temperature, which can be time-varying. This fact poses a significant challenge to the on-ground calibration of rate gyros. For that reason, in many circumstances, it may be necessary to perform regularly in-orbit re-calibrations of the rate gyros.

In this paper, we address the problem of attitude estimation with simultaneous rate gyros calibration. The solution is based on attitude measurements from star-trackers and three or more uncalibrated non-planar single-axis rate gyros. A nonlinear observer is proposed and its stability and performance properties are studied resorting to Lyapunov techniques. When compared with other estimation methodologies, such as the ones based on Kalman filtering techniques, nonlinear observers have the capability of providing stability guarantees for larger errors while yielding the same performance. The observability of the error system is studied and almost global stability is shown under persistence of excitation conditions. Numerical simulation results are presented that illustrate the performance of the proposed solution.